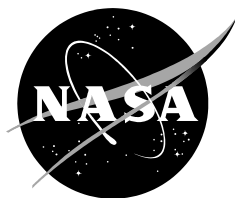


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Models of Terminal Arrival Efficiency Rate

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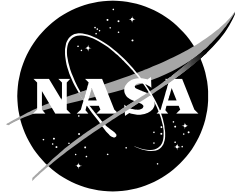
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A. Motivation

Air traffic control system aims to prevent collisions, organize and expedite the flow of air traffic. It is important to measure and monitor air traffic system effectiveness in order to identify opportunities to improve system performance. Historically, throughput and delay have been used to measure the effectiveness of air traffic management system. However, these factors are influenced by weather and other factors in addition to air traffic management. For example, airport capacities may be reduced because of weather conditions and these may, in turn, reduce throughput. Table 1 shows four different time periods with differing airport arrival capacities and demand levels. During the first and the third time periods, number of aircraft that landed is the most air traffic control could do when one considers demand and capacity. In contrast, during the second time period, actual number of aircraft landing is less than what maybe possible in ideal operations. Thus, system effectiveness during the second time period is less than during the third time period even though it would appear otherwise looking at throughput alone. This illustrates why system performance should be measured by metrics that consider factors reducing capacity.

Therefore, another metric called Terminal Arrival Efficiency Rate (TAER) has been created to measure TRACON performance and the impact of Traffic Management Initiatives (TMI) within 100 miles of the airport. This measures not just the approach control performance, but also ARTCC performance to deliver traffic evenly. This technical report documents analysis of TAER based on Aviation System Performance System (ASPM) data. Description of TAER and ASPM data in the report is from the FAA's ASPM website. [ASPM] TAER is affected by many actions including holding within 100 miles of the airport, moving traffic from one arrival fix to another within 100 miles, deviating around weather, vectoring or speed control for spacing as well as metering from ARTCC to Tracon.

Time Period	Weather constrained airport capacity	Number of arriving aircraft that would like to land (demand)	Actual number of aircraft landing
1500-1514Z	36	32	32
1515-1529Z	36	38	30
1530-1544Z	24	26	24
1545-1559Z	24	20	18

Table 1. Capacity and Demand

TAER is the percentage of the anticipated maximum number of flight arrivals that actually arrived; TAER is a maximum of 100% and a larger percentage indicates better efficiency. TAER is formally defined as the ratio of number of TFMS observed arrivals and the lesser of the Arrival Demand or the Efficiency Airport Arrival Rate. Efficiency Airport Arrival Rate is the maximum number of arrivals permitted at an airport, which is the lesser of the Airport Arrival Rate (AAR) or Ground Delay Program (GDP) rate. Arrival Demand is the number of aircraft that want to land during each quarter hour. The projected wheels on time is compared to actual wheels on time to establish the number of quarters of demand for each flight. Depending on control strategies used, air traffic system maybe in a position to an aircraft at a time between the projected wheels on time and actual wheels on time.

B. Data Used in the Study

Identifying conditions that lead to low TAER can allow development of procedures to improve system performance. In this study, we create models of TAER for Newark International Airport (EWR) that capture how it relates to variables reflecting system attributes. These variables include the following:

- Average Actual 100-to-40 nm Time in minutes (Act100): The average flight time for arriving flights from 100-miles to 40-miles from the airport for the specified runway configurations.
- Average Actual 40 nm -to-On Time in minutes (Act40). The average flight time for arriving flights from 40-miles to wheels on for the specified runway configurations in effect at the time.
- Average Excess Minutes 100 To 40 Miles (Excess100). The average difference between the actual and unimpeded time from 100 to 40 miles from the arrival airport. The unimpeded time is the average time in the previous 12-months, for the 20% of flights with the shortest travel distance, for a given 40-mile crossing point, equipment type, weight class, meteorological conditions, and runway configuration.
- Average Excess Minutes 40 To Wheels On (Excess40). The average difference between the actual and unimpeded time from 40 miles to wheels on. The unimpeded time is the average time in the previous 12-months for the 20% of flights with the shortest travel distance from 100 to 40, for a given 40-mile crossing point, equipment type, weight class, meteorological conditions, and runway configuration.
- Capacity AAR (CapAAR). The Capacity Airport Arrival Rate. The number of arrivals an airport can support per unit of time when no traffic management initiatives are in effect. For more information, see the definition for Efficiency AAR.
- Efficiency AAR (EffAAR). Efficiency Airport Arrival Rate. The number of arrivals an airport under current conditions, which is the lesser of the Capacity AAR or a reduced rate when traffic management initiatives such as Ground Delay Programs are in effect. For more information, see definition for Capacity AAR. A derived variable 'High Efficiency AAR' (HighAAR) is defined to be true when Efficiency AAR is above arrival demand.

- **Change in Efficiency AAR (ChangeEffAAR).** Change in efficiency AAR relative to previous hourly efficiency AAR
- **Arrival Demand Units.** The number of aircraft that intended to land at a specific airport per 15-minute period. Arrival demand units are reported by quarter hour, and aggregated to the hour. A single flight may have up to four units of demand in one hour. The estimated unimpeded wheels on time is compared to actual wheels on time to determine the number of units of demand for each flight. The estimated unimpeded wheels on time takes into account the aircraft weight and classification, weather conditions (IMC/VMC), runway configuration, and crossing point at 100 miles from the airport. The Start of Demand time may be adjusted for flights with start and end of demand times separated by 5 or fewer minutes, so that there is only one five-minute demand period. In Efficiency Reports, arrivals are aggregated by the end of demand hour (wheels on)
- **% Arrivals Mod+Sev Weather. (PctArrModSev)** The percent of arrivals during periods in which the weather was classified as Moderate or Severe based on the ASPM weather factors methodology. If there was no moderate or severe weather during the timeframe specified, or if there were no arrivals during the periods of moderate or severe weather, the reported value is zero. The % Hours Mod+Sev Weather field can be used to distinguish between those two situations. The Weather Factors methodology categorizes and reports on the severity of a combination of weather factors (wind speed, ceiling, visibility, nearby thunderstorms, en route thunderstorms, and airport weather such as rain and snow) in terms of their impact on flight delays
- **% Hours Mod+Sev Weather. (PctHours)** Percent of hours in which the weather was classified as Moderate or Severe based on the ASPM weather factors methodology.

C. TAER Models

Hourly EWR TAER has a mean value of 96%. Histogram of TAER is shown in Figure 1. TAER is generally worse in the presence of weather. Average TAER was 91%, 94%, 95% during severe, moderate and minor weather during 2016-2018.

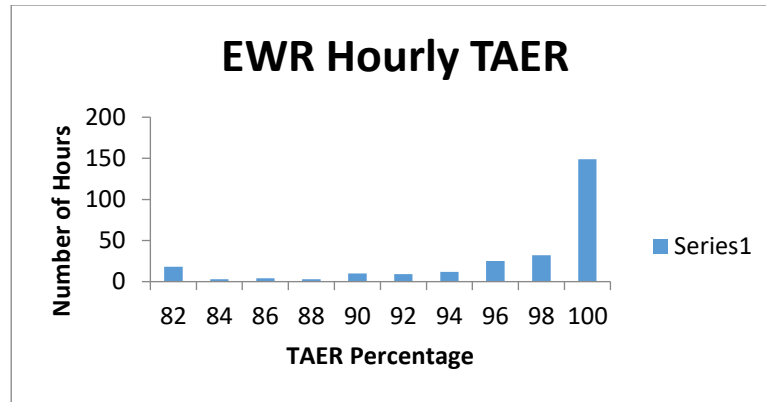


Figure 1. EWR TAER

Correlation of TAER with various independent variables

Table 2 below shows correlation of different independent variables with TAER. It shows actual and excess times of aircraft as well as arrival demand have the highest correlation with TAER. Weather is an underlying factor influencing many of these factors. We would now create a linear and a decision tree model from data.

Variable	Correlation	Variable	Correlation
<i>Act40</i>	.33	<i>Arrival Demand</i>	.27
<i>Act100</i>	.23	<i>Capacity AAR</i>	.12
<i>Excess40</i>	.39	<i>PctArrModSev</i>	.11
<i>Excess100</i>	.27	<i>HighAAR</i>	.15
<i>PctHours</i>	.11	<i>ChangeEffAAR</i>	.06

Table 2. Correlation Coefficients

Linear Models

A simple linear model of TAER in terms of *Excess40*, *Excess100*, *PctHours* and *highAAR* had correlation coefficient of .61 when July 2016 EWR data was used for developing the model. Linear equation associated with the model is $TAER = 102 - .03 * PctHours - 1.4 * Excess40 - 1.8 * Excess100 - 3.5 * highAAR$. When aircraft take excess time to arrive at the airport, one would expect a negative impact on airport arrival efficiency. Also, when AAR is low value, chances of arrival demand being above AAR is high and that makes it easier to achieve higher TAER. A more complex linear model in terms of all available variables had a correlation coefficient of .7. This reflects the fact that there are additional factors influencing TAER.

Decision Tree Model

Decision tree learning uses a decision tree as a predictive model to go from observations about an item (represented in the branches) to conclusions about the item's target value (represented in the leaves). It is one of the predictive modeling approaches used in statistics, data mining and machine learning. Tree models where the target variable can take a discrete set of values are called classification trees; in these tree structures, leaves represent class labels and branches represent conjunctions of features that lead to those class labels. Decision tree learning method was also used to create a decision tree to classify situations to have low or high TAER where low was defined to be values less than 70. Accuracy is the percentage of instances that are classified correctly. This tree had accuracy of 99%. However, accuracy is not a good metric in imbalance data in this dataset. The tree has a precision of 72% and recall of 32%. Precision is a ratio of number of true positive instances and the total positive instances. Recall is the ratio of number of true positive instances and the total of true positive and false negative instances. Confusion matrix is shown in Table 3.

Decision tree approach is particularly useful in identifying specific conditions under which TAER is likely to be low. Procedures can then be developed to remedy poor system performance during such conditions.

	FALSE (actual)	TRUE (actual)
FALSE (predicted)	43393	48
TRUE (predicted)	259	123

Table 3. Confusion Matrix

D. Conclusion

Terminal Arrival Efficiency Rate (TAER) is a measure of TRACON performance and the impact of Traffic Management Initiatives (TMI) within 100 miles of the airport. This measures not just the approach control performance, but also ARTCC performance to deliver traffic evenly. Identifying conditions that lead to low TAER can allow development of method to improve it. In this study, we developed linear and decision tree models of TAER. We found that excess time spent by aircraft within 100 miles on an airport is an important factor that influences TAER.

E. Acknowledgements

I would like to thank Rich Keller, Yao Wang, Paul Lee, Tony Evans and Mei Wei for valuable feedback on this work and this paper.

F. References

FAA. Aviation System Performance System.
https://aspmhelp.faa.gov/index.php/ASPM_Efficiency:_Definitions_of_Variables